Switch on STEM

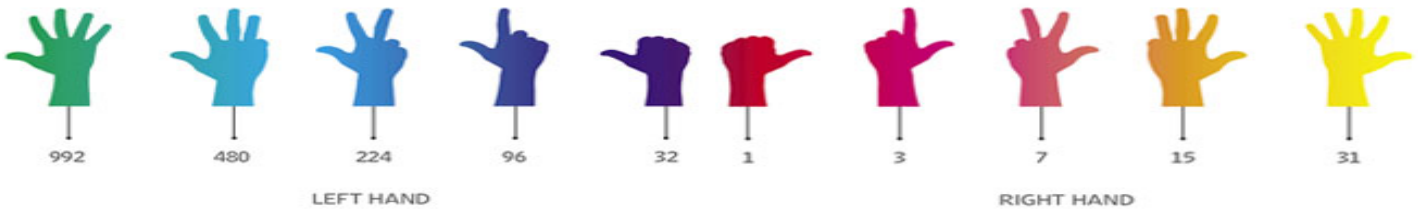
TECHNOLOGY

Binary Numbers

Introduction

Many objects have two possible states: on or off, up or down, black or white, left or right. The electronic components of computers are the same and the entire working of the computer is based on this. We can represent one state by a ‘1’ and the other by a ‘0’. Combining several of these is how computers manipulate, store and transmit information. They read a number like ‘1001’ in the binary number system, rather than the usual decimal number system. Binary numbers are at the core of every computer and understanding how machines store and send information in this way is crucial to understanding how they work, and break!

In this activity students emulate a computer by holding their fingers either up or down. In this way they learn to count to 31 on one hand, or up to 1023 using two hands! By associating each letter of the alphabet with its corresponding number, e.g. b=2, students can write messages “in binary”. Students are challenged to ‘spell out’ different words on their hands. Finally a simple method for detecting and correcting errors in message transmission is demonstrated.



Equipment

The equipment for this activity is very simple, students will mostly be using their hands!

You will need some markers to write the numbers on their fingers, some wipes to take them off and some posters to provide information.

If doing the error correction you will need some cards which have two different sides.

Preparation

- Practice counting in binary on your hands.
- Practice converting decimals to binary and also letters.

  You might want to bring a laptop to help you with this so you can use the dec2bin and bin2dec functions in Excel for example.
- Print off worksheets
- Print the posters and mount them on card for the stand.

Demonstration

- Computers represent numbers using ON/OFF switches that can only take on two values. Imagine each finger as a switch that can be either on or off. (motion putting fingers up or down). Explain the word ‘binary’ to students.
- Each digit (finger) is either a 1 or 0. We call these the binary digits or ‘bits’. That 1 or 0 represents a different value determined by its place (which finger).
- Here the digit represents the digit multiplied by the appropriate power of 2.

Finger Counting

- Write on the fingers (of the hand you write with) the increasing powers of 2: 1, 2, 4, 8, 16.
  - Start with the '1' on your thumb
  - Prompt the students to call out the powers.
- "The number I've written on each finger tells me how much that finger is worth if it's sticking up"
- Place fingers in position of some number and show the students.
  - 5 and 7 are good examples. Or start with 1 and 2.
  - Avoid 4 and 6 though – potentially rude gestures!

Student Activity

- Give the students markers to write the numbers on their hands.
  - Make sure they write on their dominant hand using the ‘wrong’ hand for writing. It should be fun!
- Ask them to show you different numbers
  - Warm up with easy ones like 2 and 5.
  - 17, 18 and 19 are good further examples.
  - 15 and 9 are tricky to manage – try them!
- Ask or show the students to count to 30.

Further Questions

- Ask the students what 31 looks like.
  - All fingers up – an open hand or ‘high five’.
- Write the next powers of 2 on your other hand: 32, 64, 128, 256, 512.
  - Prompt the students for the numbers again.
  - Let the students finish their hands too.
- Ask the students what 1023 would look like:
  - All fingers on both hands up.
- Challenge them to express some large numbers in binary on their hands and on the worksheet.

Letters

- Ask the students: “How do you think we might extend this system to letters?”
  - There are 26 letters in the alphabet and we can represent numbers up to 31 on one hand.
  - Point out the poster with the letter-to number correspondence.
- Ask the students to ‘spell out’ an easy word like ‘hi’, ‘ace’ or such.
- Help students to ‘spell out’ their names and write the binary on their worksheets.

Notes

- At each stage you will be showing the students how to ‘spell out’ numbers/letters in binary.
- You will ask them to signal number and letters to you.
- You should also ask them to guess what number/letter your hands represent with various examples.
- Make sure they understand what binary means and how computers store numbers and letters as binary.

Background Information

- Computers represent numbers using 1 and 0.
- As humans, we use a number system in which numbers are constructed of digits which each take on one of 10 different values : 0, 1, 2, 3, 4, 5, 6, 7 ,8 ,9.
- When we write down a number we use a combination of these 10 different digits to represent the number. In the decimal number system each digit has a value determined by its place in the number: The 2 in 121 has value '20', the 2 in 42 has value 2, the 2 in 234 represents 200.
- The value depends on whether it is in the 'units, tens, hundreds,' column or position. It represents the digit multiplied by the right power of 10.

- Computers find it more difficult to represent 10 different digits. Computers are built using electronics which can more easily store values which have two different values, rather than 10 different values. Computers can easily recognise where a switch is turned ON or OFF. They can easily recognise if a signal if HIGH or LOW. Computers deal most easily with states that can take on two values, or so called BINARY states.
- To store a number in a computer or to transmit a number on a computer network, that number needs to be represented as a sequence of BINARY states. This means that the computer can then represent it in electronics using a sequence of switches which are either ON or OFF, or can represent it in a computer network as a sequence of signals which are either HIGH or LOW.

- The BINARY number system is the number system used by computers which uses digits that have two values (1 and 0) instead of the 10 values used in the DECIMAL number system. In the binary number system, a DECIMAL number such as 25 is represented using the BINARY digits 11001. If a computer wants to represent this number it will need 5 switches which it can turn ON or OFF, or it will need 5 signals to be transferred across a network which are HIGH or LOW.
- If a computer is storing or transmitting text, it maps each letter in the text to a number, and then represents the number in binary, and then stores or transmits the binary number in ON-OFF switches or HIGH-LOW signals.